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IRRIGATION AND FLOODING PROBLEMS IN MICHIGAN

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Irrigation and flood control as they relate to agricultural and rural land use in Michigan are studied. Also included is the influence of urban areas on rural areas in watershed management. The components of watershed management considered include: irrigation, flooding, transportation, recreation, pollution, consumptive and non-consumptive uses of water, surface vs. ground water for irrigation, the riparian doctrine, flood plain management, and use of structural devices vs. nonstructural methods.

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IRRIGATION AND FLOODING PROBLEMS IN MICHIGAN

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July, 1976

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INTRODUCTION

This paper considers two closely related issues of watershed management; specifically the problems of flooding and irrigation. Although flooding problems and the need for irrigation often are thought of as different problems they are in fact inter-related. A watershed may experience severe flooding problems during one season and require irrigation during another. In such cases irrigation and flood protection policies have to be designed so that the two strategies can be integrated.

Michigan as a whole experiences a well balanced pattern of precipitation. The average monthly precipitation is relatively constant and at a level so that there are very few excessively wet or dry periods. There are, however, a sufficient number of areas in the state that require flood protection or irrigation or both to require consideration of the problem.

Primarily the paper deals with irrigation and flood control as they relate to agricultural and rural land use in Michigan. However, it is not possible or desirable to ignore urban problems since actions taken in one part of a watershed spill over into other parts. The influence of urban areas on rural areas, through their demands for water and land alone, is so great that they must be considered. For analytical purposes the questions of flood plain management and irrigation are treated in two distinct sections that are followed by a summary and conclusion.

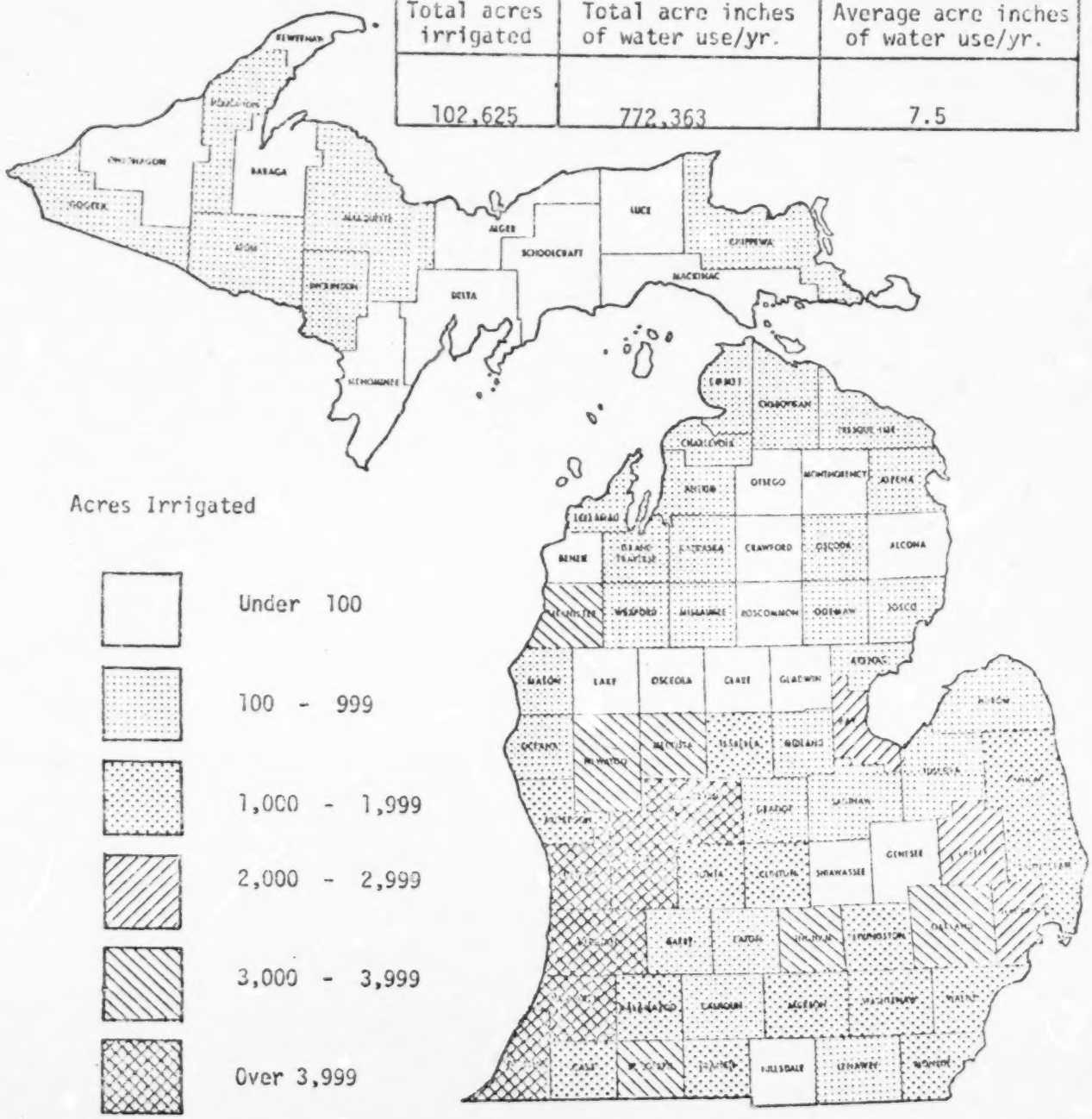
IRRIGATION

In general irrigation is not commonly associated with agriculture in Michigan. In most areas of the state one of the major problems encountered by farmers is too much water necessitating large investments in draining land. However, as Figure I indicates, there is some irrigation in the great majority of Michigan counties and in several areas irrigation is very important. Most irrigated land is used for agricultural purposes, primarily for the cultivation of potatoes, truck crops, and strawberries. However, non-agricultural uses of irrigated land such as golf courses,

Figure 1

Irrigation Distribution Map (Total)

Total acres irrigated	Total acre inches of water use/yr.	Average acre inches of water use/yr.
102,625	772,363	7.5



Source=Michigan Department of Natural Resources Water Development Services Division, Irrigation in Michigan: 1970, Lansing, Michigan.

sod farms and other recreational uses are important. Although agriculture is the largest absolute user of water, the most intense use of water is non-agricultural. Golf courses apply almost 17 inches per year while the average agricultural use is under 7.5 inches [1, p. 1]. Typically water is classified by consumptive and nonconsumptive uses. All uses of water affect the quality of the water. In addition consumptive uses alter the quantity of water returned to the source. A consumptive use such as irrigation puts a smaller quantity of water back into the system leading to a diminished flow of water for downstream uses. As noted previously, irrigation is a relatively minor use of water in Michigan when compared to any of the other major uses, as Figure II indicates. However irrigation, unlike many other uses, results in considerable water loss through evapotranspiration as well as changes in the quality of the residual water.

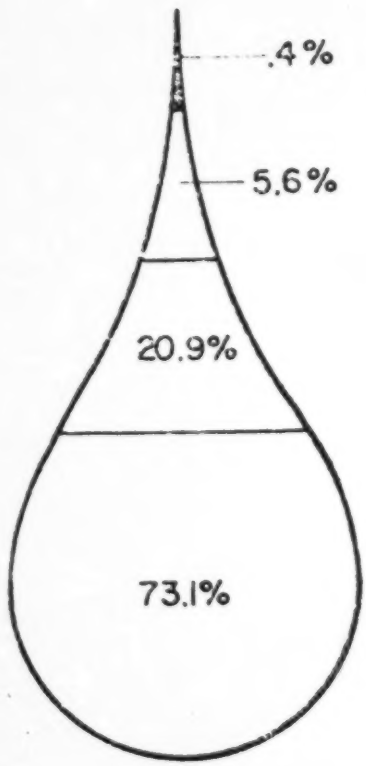
The source of water for irrigation is of some interest. More than half of the water uses for irrigation is obtained from surface water [1, p. 1]. The use of surface water is far more visible than when ground water is used for irrigation. If water is pumped out of the stream there may be noticable effects of the quality of the water even if most of it returns to the stream since it usually contains heavy sediment and fertilizer loads. Even where ground water is used for irrigation there is some drawn down of the aquifer. If the pumpage rate is high this could lead to a loss of water for individuals within the cone of depression. Ground water can also be contaminated by irrigation practices. Chemicals from fertilizers and pesticides which are water soluble are not removed by filtration through the soil.

Michigan water law is based on the riparian doctrine which entitles land holders with water front property to use the water flowing by them but requires that they not harm the interests of other users [14]. This means that the individual may be allowed to consume a reasonable quantity of water but he cannot remove large quantities of water from the stream permanently, nor can he adversely affect the

Figure 2

MAJOR WATER USES IN MICHIGAN 1970

IRRIGATION	13 BGY	.4%
RESIDENTIAL	204 BGY	5.6%
INDUSTRIAL	759 BGY	20.9%
POWER GENERATION	2,662 BGY	73.1%
TOTAL	3,628 BGY	



Source: Michigan Department of Natural Resources Water Development Services Division, Irrigation in Michigan:1970, Lansing, Michigan.

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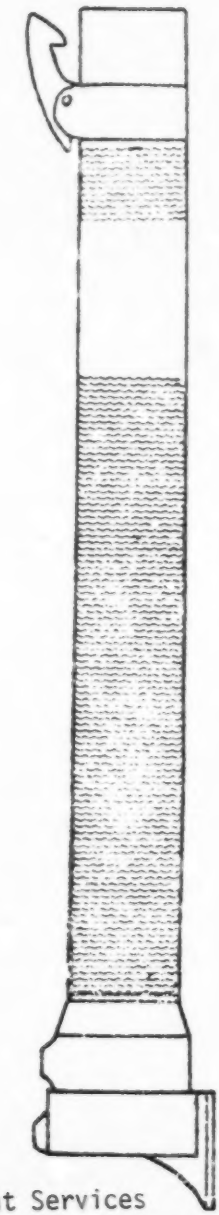
Figure 3

TOTAL IRRIGATED LAND IN MICHIGAN 1970

	ACRES	%
MISCELLANEOUS	377	1
COMMERCIAL	12,846	12
RECREATION	15,997	16
AGRICULTURE	73,425	72
TOTAL ACRES	102,625	



Source: Michigan Department of Natural Resources Water Development Services Division, Irrigation in Michigan:1970, Lansing, Michigan.

quality of the water flowing past his property. For a brief analysis of the development of Michigan water law see[18]. Diversion of water for irrigation purposes can be readily challenged by downstream riparians since the flow of water can be significantly diminished by such use.

In a conflict between irrigation and other uses it is likely that irrigation will be the loser. Irrigation generally cannot bid water away from alternative uses when water is sold on the market. If a hierarchy of water uses in Michigan is considered irrigation water is to be found beneath human consumption, industrial use and recreation. Thus in a competitive situation irrigation tends to be a residual use for water. In addition alternative uses of water tend to have large interest groups supporting their policies whereas irrigators for the most part are relatively few in number, unorganized and lack a common interest. These factors, when considered with the bias of the riparian doctrine against consumptive use of water, suggest that irrigation will only be employed when no other user group perceives a water shortage.

Of the users of water for irrigation, agriculture is most likely to be affected by water shortages. Not only is agriculture the largest user of water for irrigation but it has the least ability to pay. Since irrigation in Michigan is used to increase yeild, not as a necessary input, the demand for water is likely to be highly price elastic[17, p. 42]. As water costs increase farmers can be expected to limit their use of water. Water used for agricultural irrigation is of very indirect benefit to the public whereas irrigation for many nonagricultural uses of water is a direct and important part of the product. For example golf courses that are not well watered lose their appeal rapidly, as does any form of dry grass. These latter uses are much more likely to continue to irrigate if the price of water rises than is agriculture.

Because water used in Michigan for agricultural irrigation is applied to

increase the yield rather than to allow the actual growing of the crop, the marginal increase in yield is generally low enough that water would not be applied were the costs of irrigation to increase. At present the principle use of irrigation water in Michigan is for the prevention of frost damage [6]. This would suggest that in Michigan agricultural irrigation must either be subsidized or use water that has no other economic use. Water used for irrigation is a substitute for other inputs such as land. Heavy use of irrigation is generally accompanied by increased use of fertilizer because of leaching problems and the greater fertilizer requirements of the more densely planted crop. As practiced in the United States irrigated farming requires extensive use of fossil fuel based inputs such as machinery and fertilizer. Thus irrigation in this form is part of the capital and energy intensive mode of production common to advanced economies [16].

In the past Michigan agriculture has not experienced major problems obtaining sufficient water for irrigation. However, as the population increases, increased demands for water for consumption, industry and recreation will arise. Eventually the fixed supply of water will not be sufficient to meet existing demands and some means of allocating the water among alternative uses will have to be found. Unless there is a significant change in agriculture's ability to pay, it would seem that agricultural irrigation will be one of the first water uses in Michigan to be restricted.

FLOODING AND FLOOD PLAIN MANAGEMENT

Concern with drainage and flooding problems has a long history in Michigan [18]. The riparian doctrine deals not only with the right to use water but also with the right of an individual to alter the flow of water courses and drain land. Thus, a large body of common law exists dealing with drainage problems. In addition to the common law, statutes such as the Michigan Drain Code and the Floodway Encroachment Act provide specific regulations for the management of water. Federal

legislation dealing with flood control and aid to flood victims is also of great importance to Michigan. For a summary of water related legislation in Michigan see [11].

Floods

Generally major flooding in Michigan occurs in the spring during the melting of the winter's accumulation of ice and snow. However, localized floods can occur at other times of the year following an exceptionally heavy rainfall if the capacity of the local drainage system is exceeded.

Two stages in the flood process can be distinguished. The first is the land phase where precipitation accumulates on the surface of the land because the soil cannot absorb the moisture as quickly as it falls. This is the phase of flooding that in general influences agriculture the most. As the soil becomes saturated the water begins to flow off causing soil erosion and possibly crop damage. In addition, if the precipitation occurs at an inopportune time, planting or harvesting may be delayed until the soil dries out enough to allow the use of field equipment. Heavy spring rains are especially important in Michigan since delays in planting can result in significant yield reductions, because of a reduction in the growing season. In addition very wet soil is harder to work causing increased fuel consumption, greater wear on equipment, and further losses in time. Heavy rains can also provide environments favorable to insects and bacteria that can affect crop yields. In summary, the major effects of the land phase of floods in agriculture are increased costs, loss of time and soil erosion.

The second phase of a flood -- the channel phase -- begins where the water flowing along the surface of the land reaches the streams and rivers. The channel phase of floods is the more spectacular and visible phase and has received the greatest attention. As the surface runoff increases, the volume and flow rate of the river increases. As the volume of water increases, the river channel begins to fill

and if the flow becomes large enough to exhaust the channel capacity, the river spills into the flood plain. It is at this stage that people generally feel the greatest impact of a flood because the river is now occupying land that is normally dry.

Flood Plains

Although the flood plain may only be inundated infrequently it is an integral part of the river. The exact shape and extent of the flood plain is determined by a combination of hydrological, geographical, geological, and human forces. The relative importance of each of these forces varies from river to river. Generally the river channel is large enough to carry a relatively large increase in volume. It is not able to carry the very infrequent exceptionally large floods. If we consider how the river channel is formed it is obvious why this is so. Over 95 percent of the energy in a river is dissipated through frictional losses such as bank shearing and erosion. It is these frictional forces that form the river channel. Except in times of extreme flood the volume of water is small enough that these erosive forces are confined to the channel and do not spill over into the flood plain. Only with the very infrequent high volumes and flow rates of major floods is the river able to modify the entire flood plain. It is necessary that from the onset it be recognized that the flood plain is part of the river and that at some time the river will occupy the flood plain [14, p. 23] .

There is, however, some problem in defining the boundary of the flood plain. Since it is impossible to know the maximum conceivable flood it is also impossible to know the maximum extent of the flood plain. Generally flood plains are defined in terms of historical information on floods and associated probability distributions. Thus, the hundred year flood plain may be defined as the area of land that would be occupied by a flood of magnitude that would be expected only once in one hundred years. Unfortunately, such assumptions are unwarranted since the flood plains are defined in terms of expected occurrences and not as determinate events governed

by conditional probabilities.

Flood Plain Use

The occupation of flood plains by man introduces the element of economic damage from floods. Given the fact that floods can be expected to occur then the decision to occupy the flood plain must involve a consideration of the projected costs and benefits of such use. Various reasons for occupation can be found. Generally flood plains are flat and consist of fertile soil with good water supplies making them ideal agricultural land. These characteristics and the presence of the river as a transportation system also encourage the development of settlements. Once a community has become established on the flood plain it tends to attract further development. If major floods are infrequent it is possible for several generations of individuals to live in the flood plain without experiencing a flood. In such situations it becomes easy to forget that the land is susceptible to flooding and hence the costs of a flood is not considered in the decision process.

If we consider individuals contemplating building on a flood plain we can think of their decision process in terms of the theory of decision making under uncertainty. The benefits of the flood plain such as better location and other attributes must be weighed against the cost of possible destruction. However, such a decision is complicated by the fact that only limited information about the probability distribution of the flood is available and that various levels of destruction can occur depending on the type of flood and the time of occurence. An "economically rational" individual will weigh the utility of the discounted stream of expected benefits against the discounted stream of expected costs in making decisions.

Further complications to the decision process are introduced by the introduction of externality problems. Because of federal, state and local aid to flood victims individuals do not bear the full costs of their actions. Consequently, there is a divergence between the social cost of developing a flood plain and the private

cost to the individuals.

Structural Management Programs

In the past, flood plain management has relied primarily on engineering devices such as dams, levees and channel diversions to control flood waters. These devices have been built using public funds so that the beneficiaries receive benefits far in excess of their contribution to the costs. In addition, it is possible that upstream and downstream riparians may actually be harmed by such devices. If a reservoir is built upstream to contain the water from a flood and to then gradually let it discharge, the upstream residents lose the land that is flooded by the reservoir. Similarly, if channels and levees are built to funnel the water safely through one area then the downstream region may bear the cost of the flood.

This is not to say that such action may not be justifiable. The value of the protected area may be far in excess of the upstream and downstream reaches. The point is that the costs experienced by these other areas must be taken into account if a true picture of the costs is to be obtained.

The cost of structural devices such as dams and levees is generally so great that only urban areas are protected by these works. Agricultural areas generally bear significant costs from such devices in the form of condemnation of land from reservoirs or increased flood damage from levee channelization. As the urban areas of Michigan expand there is a great temptation to do so by developing flood plains, especially given the existing institutional arrangement where costs are subsidized. This means that non-residents of the flood plain are likely to continue to subsidize flood plain residents.

Despite the large expenditures on flood control since the turn of the century the economic damage caused by flooding continues to increase. This suggests two "fundamental propositions". First, that flood control programs have been ineffective and second, that despite floods people see a great value in occupying flood plains.

The existence of this phenomenon can be partially explained as follows. In general, property values have increased leading to increased damage. Damage reporting techniques have improved so that more damages are considered than previously. Changes in the frequency and magnitude of floods may have occurred [26, p. 7-21]. These explanations are not policy variables in the sense that we can or would want to do anything about them. The two "fundamental propositions" do, however, lead to some interesting questions regarding the optimal use of flood plains and appropriate techniques to prevent flood losses.

Previously we have noted some of the reasons for increased occupancy of the flood plain. Given these reasons and the fact that society has provided subsidies to the occupants of flood plains it is natural that flood plain development should occur. As the degree of subsidy increases we would expect the degree of occupancy to increase ceteris paribus. Past experience with flood control expenditure is consistent with this expectation [20]. In the past flood plain management has relied primarily on structural or engineering devices to provide protection. In the face of increasing costs of flood damage despite these expenditures it would seem that other options should be considered.

Federal Flood Control Programs

The two federal agencies with primary responsibility for flood control are the Army Corps of Engineers and the U.S. Department of Agriculture's Soil Conservation Service. The division of authority between these agencies is unclear and there has been considerable conflict and controversy over the appropriateness of their actions and responsibilities in the past [9, 10].

The Corps has traditionally relied on engineering devices and its major area of interest has been the protection of urban areas. Such areas are often best protected by large dams and their associated reservoirs on the major branches. As

noted above this shifts much of the cost of protection onto the rural area which is turned into a reservoir for the urban areas benefit. Such projects have high capital costs which are spread over the general population since the federal budget is the primary source of funds.

The Soil Conservation Service has been primarily concerned with erosion caused by the land phase of floods. Flood control is a secondary interest. By fostering the adoption of the proper conservation practices the runoff from the land to the streams can be minimized to help reduce flooding [6]. Although proper cultivation can result in significant reductions in runoff for a small area with a normal amount of precipitation such practices are of limited value if the storm is exceptionally heavy or covers a large area. In addition to the conservation program the Department of Agriculture undertakes the construction of small dams on the upper tributaries of watersheds. These dams and their associated reservoirs provide benefits for the immediate area of the dam but do not provide much protection for the downstream areas.

In their study of the Small Watersheds Program, David, Ingle and Gillen note that floodwater retardation and channel improvement represented over half the installation costs of the program [22, p. 83]. A large portion of the channel improvements were undertaken to improve drainage of agricultural land permitting increased crop production. A side effect of the improved drainage is an increased flow of water downstream which may compound flooding problems. Like the Corps, the Soil Conservation Service makes most of its expenditure on structural and engineering devices. As of June 30, 1970, 72.3% of the installation costs had been for structural measures and 27.7% for land treatment measures [22, p. 83]. The authors conclude that many of the works undertaken by the Soil Conservation Service are of questionable value when the total costs and benefits to society are considered.

Even if an unlimited supply of money were available so that upstream and

downstream dams could be built it does not follow that they should be. As long as the construction is financed by general taxes the residents of the watersheds will be subsidized by society. Only if society consciously undertakes to subsidize these areas could such action be justified. Even then a more efficient way of transferring money may be available. In the next section alternatives to the federal programs of flood plain management which will shift the burden of cost onto those who reap the benefits will be proposed.

Non-Structural Flood Plain Management Programs

As the name suggests, these programs do not attempt to control floods by physical construction. Rather, they influence how the flood plain is used by society. In looking at non-structural control measures a three-part classification will be employed. The criterion for distinguishing methods will consist of a continuum based on market and regulatory forces. Different methods will be discussed within this framework with respect to strengths and weaknesses of different approaches.

In a sense all these non-structural methods are regulatory devices because they influence how a flood plain is used. Market oriented methods work by using existing market pressures or by creating new market forces. Once the market has been designed there is not direct interference with the use of the flood plain. Direct regulation in contrast specifies uses that will be allowed or prohibited and requires direct enforcement and continuous monitoring of the flood plain. Many of the problems associated with flood plain use and management can be thought of as arising from market failure. Given this failure there are two alternatives. The first is to find the cause of the failure in the market mechanism and to correct it. The second is to replace market control with direct control.

Direct controls have been the popular solution to flood plain management [24, p. 1]. Zoning regulations specifying the types of uses for land in a particular area are often suggested as an alternative to structural devices. If you prohibit

people from occupying a flood plain you remove the need for flood protection. Thus, in theory, zoning would seem to be an adequate solution. By analyzing historical data it should be possible to distinguish between zones by varying levels of risk. Within each zone certain acceptable activities could be specified so that the flood plain is utilized in a socially beneficial manner.

Zoning would be a more appropriate action if the flood plain in question was undeveloped eliminating the necessity of dealing with already existing structures and uses. Imposing zoning in a situation where people have developed long standing rights and practices becomes a very difficult process requiring compensation of the owners and the use of government police powers. In addition the optimal use of a parcel of land can change over time. An ideal zoning system would be flexible enough to take account of these changing conditions. In practice, once a zoning system has been established, a bureaucracy develops that administers the control mechanism. This bureaucracy in turn has little incentive to consider alternative uses of the land to determine how the regulations should be changed and thus lead to the long-term freezing of permissable uses.

Other regulatory techniques include direct acquisition of land by government, and the use of building codes. Direct acquisition can be thought of as the ultimate form of zoning. The government acquires title to the land either by compensation or some other means and then uses it for what it considers to be a socially optimal purpose. Criticisms of the zoning process noted above also apply to direct acquisition.

Building regulations can be used for two purposes. The first is a form of indirect zoning where the building codes are designed to prohibit certain uses. The second and more useful purpose is to ensure that buildings in a flood plain are designed to minimize flood damage. Floodproofing of buildings minimizes the costs of a flood by requiring buildings to adopt specific designs and methods of construction that keep water out. Such regulations include requiring the sealing of

basements with a water impervious substance, requiring elevated sills on all openings and the prohibition of living in basements.

At the opposite end of our "market-regulation" spectrum we have market oriented solutions. One of the principle complaints against structural flood control methods is the divergence between social and private costs. Dams and other devices that are constructed by public expenditure provide benefits to flood plain residents for in excess of the costs they incur. In this case individuals do not consider all the costs of their actions of occupying flood plains since they are not forced to pay for all of these costs. Market oriented solutions seek to force individuals to consider and abosrb all the costs and benefits of their actions. If this can be done there will be no divergence between social and private welfare, given certain other standard assumptions. If a competitive market can be established it would be self-regulating and self-adjusting obviating, in principle, the need for an on-going supervising bureaucracy.

One suggested means of approaching a competitive market process for determining the use of flood plains is flood insurance [24, 30, 19, 23]. If individuals can purchase flood insurance at actuarially fair prices then the costs of the flood will be covered by the premiums paid by the individuals. If all residents of a flood plain buy such insurance then there is no divergence between social and private costs. Residents take the total cost of their actions into account since the insurance premiums are equal to the expected value of the loss from flooding. Only those activities where net benefits from residing in a flood plain are positive will be undertaken.

There are, however, some problems with a flood insurance program. When a flood does occur, damages are of a large magnitude and concentrated in a specific area. This makes it difficult to employ conventional insurance practices. An individual company will have great difficulty in obtaining a large enough pool to allow it to

offer acceptable premiums. This suggests that flood insurance would be best administered through national programs. In addition, unless it is compulsory or there is no possibility that the state will provide flood disaster aid, there is an incentive for the individual not to purchase insurance. If this happens, the point of the program is lost. This suggests that flood insurance, if it is adopted, should be compulsory for residents of flood plains [24].

In the middle of the continuum are what will be called neutral measures that are neither market nor regulation oriented. Such measures improve information so that individuals and governments can make their decisions in a less uncertain environment. Increased information about flood frequency and actual damage contributes to our knowledge of the risk and potential costs of floods. Flood warning signs designating areas that are susceptible to floods and requirements that land titles in flood zones be labelled as such substantially enhance the information for prospective occupiers of a flood plain.

The Optimal Combination

In practice, some combination of structural and non-structural methods will provide the greatest benefit. Structural and non-structural measures are in a sense complementary. A combination of the two approaches rather than reliance on one will give a higher net benefit in most cases. Structural measures which are created to control the flood in cases where the flood plain is of great value may be justifiable. It may, however, be better for society to ensure that only activities that can withstand the costs of floods be sanctioned for flood plains. Then the river could be allowed to follow its natural course without society having to compensate individuals for their losses.

As the population of Michigan grows, there is increased pressure for development of the flood plains. This results from increasing urban concentration and the fact that a large number of Michigan cities are located on rivers. As urban land

becomes more valuable, expenditure on structural devices to allow development of the urban flood plains may be promoted. However, such expenditures have effects outside the immediate area of development. Such devices may cause increased flooding either upstream or downstream depending on whether dams or channels are used. Furthermore, the costs of the construction are likely to be borne by the population as a whole rather than by those that reap the benefits. These costs include the construction costs and the costs of cleaning up a disaster if the structures fail.

Rural areas and urban fringe areas will not in general be able to justify structural devices solely on the basis of flood control. They may, however, be justifiable if they are multi-purpose constructions. A dam that provides irrigation water and recreational facilities in addition to a flood control function may be a justifiable project. As noted above, control of runoff during the land phase of a flood is the first place to implement flood control. Proper cultivation and planting practices can control the discharge into the streams. This not only spreads the discharge over a longer period of time but also reduces the volume of water in the runoff since the soil absorbs more.

Flood control is an integrated process and the services of any specific program required planning over an entire watershed. Piecemeal efforts, although they may solve localized problems, will in general cause greater problems in some other part of the watershed.

CONCLUSION

Irrigation or flooding are only two parts of the watershed management problem. Additional components are transportation, recreation, and pollution. All these aspects are interrelated and in attempting to adjust one part of the problem, impacts on the others. Both irrigation and flood plain management involve important issues in public and individual choice which require resolution before an actual management

strategy can be proposed. Hopefully this paper has helped to clarify some of the underlying aspects of this problem.

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